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(54) HIGH PERFORMANCE IMPULSE INK JET METHOD AND APPARATUS

HOCHLEISTUNGSIMPULS TINTENSTRAHLVERFAHREN UND GERÄT

APPAREIL A JET D'ENCRE IMPULSIONNEL HAUTE PERFORMANCE ET PROCEDE CORRESPONDANT

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Description

Field of the Invention

[0001] This invention relates to drop-on-demand or impulse fluid jets which eject a droplet of fluid such as ink in response energization of a transducer which may take various forms according to the preambles of claim 1 and claim 12 respectively.

[0002] US-A-4 686 539 discloses a method for driving an ink jet head, comprising the steps of producing a composite drive waveform having, for each drop of ink, at least first, second and third electrical pulses for ejecting from said ink jet head respective first, second and third ink droplets having successively higher relocities upon exit from said head, whereby said droplets merge in flight for producing an ultimate ink drop.

[0003] US-A-4 491 851 discloses a method for driving an ink jet printer which includes an electromechanical transducer which is operated by electrical pulses to eject ink from an ink nozzle connected to pressure chamber wherein two successive electrical pulses are supplied to the transducer before the ejected ink is separated from the remaining ink in the pressure chamber.

Background of the Invention

[0004] Impulse fluid or ink jets are designed and driven so as to eject a droplet of fluid such as ink from the chamber through an orifice of the ink jet device. In many applications, it is not necessary to operate the ink jet device at high performance levels, *i.e.*, at high velocities and long throw distances. However, many applications including industrial applications require high performance ink jet devices.

[0005] For example, in various industrial ink jet applications, it is very important to eject droplets at high velocities with long throw distances so as to reach targets some distance from the ink jet orifice while maintaining a relatively small droplet size to create a high resolution dot on the target itself. In order to achieve this result, it is important that the head of the droplet as well as its tail remain attached to each other and travel at the same relatively high velocity.

[0006] In the prior art, it has been difficult to achieve high velocity and long throw distances. For example, with expanding piezoelectric transducers in ink jet print heads of the type disclosed in U.S. Patent No. 4,646,106, high performance is achieved in terms of frequency response using fluidic Helmholtz frequencies of from 25 to 50 kHz and comparable piezoelectric length mode resonant frequencies. However, the droplets formed have long tails which tend to lower the droplet velocity and the throw distance thus precluding optimum performance.

[0007] U.S. Patent Nos. 4,523,201 and 4,523,200 disclose similar print heads driven by voltage waveforms having a first pulse of longer duration and a second pulse of shorter duration designed to achieve early break off of the droplet tail. However, the devices disclosed therein are designed to operate at Helmholtz frequencies of less than 50 kHz and there is no disclosure of the effect of exciting higher harmonic frequencies to achieve break off of the tail for producing higher velocity droplets with improved throw distance. Rather the second pulse merely improves aiming.

[0008] Reference is now made to Figs. 1A through 1F which schematically depict the drive waveform in Fig. 1A and the ink jet device itself at various points in time in Figs. 1B through 1F. Referring to Fig. 1A, the drive waveforms depicted with voltage on the ordinate and time on the abscissa. At time A, the ink jet device as depicted in Fig. 1B is maintained in the quiescent state with the transducer 10 unenergized and a predetermined volume of ink 12 contained within the chamber 14 behind an orifice 16. At time B as shown in Fig. 1A, the transducer 10 is driven by the voltage pulse 17 as shown so as to contract the length of the transducer 10 thereby increasing the volume of ink 12 within the chamber 14 and pulling back the meniscus 18 in the orifice 16 to the position shown.

[0009] As shown in Fig. 1C, which corresponds to time C of Fig. 1A, the transducer 10 begins to expand as the voltage is reduced as applied to the transducer 10. As a result, the volume of ink 12 within the chamber 14 begins to contract while advancing the meniscus 18 through the orifice 16 as shown in Fig. 1D. At a slightly later time than C but before D as shown in Fig. 1E, the transducer 10 has nearly returned to the quiescent state as shown in Fig. 1E and a droplet 20 with a ligament 21 has begun to form at the orifice 16. In Fig. 1F which corresponds to time D in Fig. 1A, the droplet 20 has traveled some distance from the orifice 16 with a slowly moving tail 22 attached. As depicted in Fig. 1F, the tail 22 has just broken off from the meniscus 18 at the orifice 16 before the volume of ink within the chamber 14 returns to the condition shown in Fig. 1B. As can be readily seen from Fig. 1F, the tail 22 is elongated in a manner so as to create a "lay over" condition on a target assuming the tail 22 and the head 20 remain attached throughout their flight to the target. Tail 22 which is relatively slow moving as compared to the head velocity which makes the tail grow in length and break up thereby decreasing the overall throw distance to the target.

[0010] In the devices of the prior art of the type disclosed in U. S. Patent Nos. 4,459,601, 4,509,059, 4,646,106 and 4,697,193, ink jet devices have been characterized by Helmholtz resonant frequencies of approximately 40 kHz and piezo length mode resonant frequencies of 45 kHz. The tail which was formed at the meniscus saw pressure disturbances of approximately 45 kHz. As a consequence, the tail would be broken off as shown in Fig. 1F in response to this disturbance during the negative velocity part of the cycle so as to provide a very low acceleration component thereby producing a drop with a high head velocity and low tail velocity and

a tail that grows longer over long print gaps producing poor print quality.

Summary of the Invention

[0011] In accordance with this invention, a high performance fluid jet method and apparatus is provided wherein high velocity droplets are ejected from the fluid jet device.

[0012] In further accordance with the invention, a high performance fluid jet method and apparatus are provided wherein the droplets have a large throw distance to the target.

[0013] In further accordance with the invention, the method of operating an impulse fluid jet device is provided wherein the device comprises a chamber and an orifice for ejecting droplets from the chamber and a transducer having a resonant frequency and a higher harmonic frequency. The method comprises the steps of generating one energy pulse of one duration coupled to the transducer for exciting the resonant frequency of the transducer. Droplet ejection is initiated such that the droplet has a head and a tail attached in response to the one energy pulse. Another energy pulse of another duration is also generated and coupled to the transducer, the other energy pulse having substantially shorter duration than the one energy pulse for exciting a higher harmonic frequency. The attached tail is broken off from the head of the droplet in response to the other energy pulse. As a result, the head and the remainder of the tail travel together toward a target.

[0014] In one preferred embodiment of the invention, the other pulse follows the one pulse in time. In another preferred embodiment of the invention, the other pulse precedes the one pulse in time.

[0015] In accordance with another important aspect of the invention, the droplet of fluid or ink including the head and the attached tail comprise at least 20 picoliters and preferably more than 60 picoliters, preferably travel at a velocity in excess of 6 meters per second, and preferably have a travel distance or throw distance of at least 0.25 inches and preferably more than 0.5 inches.

[0016] In accordance with a further important aspect of the invention, the transducer has a resonant frequency in excess of 50 kHz and preferably in excess of 75 kHz and a higher harmonic in excess of 150 kHz and preferably in excess of 200 kHz.

[0017] In accordance with another important aspect of the invention, the fluid or ink jet chamber is of a volume so as to preferably have a Helmholtz frequency in excess of 50 kHz.

[0018] In the preferred embodiment, the duration of the one pulse is greater than 5 microseconds but less than 100 microseconds and the duration of the other pulse is greater than .5 microseconds but less than 6 microseconds. The time delay between the one pulse and the other pulse is greater than 1 microsecond but less than 5 microseconds.

Brief Description of the Drawings

[0019]

Figs. 1A through 1F are diagrammatic, partially schematic representations of the prior as discussed above.

Fig. 2A is a waveform for driving a fluid or ink jet device in accordance with the invention.

Fig. 2A' is an alternative waveform for driving a fluid or ink jet device in accordance with another preferred embodiment of the invention.

Fig. 2B is a partially schematic representation of a fluid or ink jet device in accordance with this invention being driven by the waveform of Fig. 2A or Fig. 2A' as the droplet emerges from the ink jet device.

Fig. 2C is a partially schematic representation of a fluid or ink jet device which represents the device of Fig. 2B at a slightly later point in time.

Fig. 3 is a partially schematic/block diagram of an jet printing apparatus which may be utilized in practicing the invention;

Fig. 4 is an alternative voltage waveform which may be used in another embodiment of the invention;

Fig. 4a is yet another alternative waveform which may be used;

Fig. 5 is a circuit diagram depicting a resistor in series with a length mode piezoelectric electric transducer driven by the signal generator of Fig. 3 using the various waveforms contemplated by this invention; and

Fig. 6 depicts the resonant frequency of the transducer and a higher harmonic superimposed on drive waveforms which achieve a droplet having a high velocity with a long throw distance.

Detailed Description of the Preferred Embodiments

[0020] Reference will now be made to Fig. 2A wherein a piezoelectric transducer voltage drive waveform is shown in accordance with one preferred embodiment of the invention. One pulse 23 after time A and between times B and C is generated and applied to the piezoelectric transducer so as to contract the transducer as shown in Figs. 1B and 1C. However, unlike the prior art voltage waveform of Fig. 1A, another pulse of shorter duration immediately follows the one pulse beginning at time E and terminating at time F. In accordance with this invention, the one pulse between times B and C excites the piezo resonant frequency, while the other shorter pulse between times E and F excites a higher harmonic frequency of the piezoelectric transducer. This higher harmonic frequency has a high acceleration component and enough amplitude to disturb the tail formation seen in the prior art representation of Fig. 1F as will now be described with reference to Figs. 2B and 2C.

[0021] As shown in Fig. 2B, the pulse 23 between times B and C forces the droplet 20 connected to the ink

12 within the chamber 14 outwardly from the orifice 16 similar to that shown in the prior art Fig. 1E. However, the shorter pulse 25 between times E and F as shown in Fig. 2A excites a higher harmonic of the piezo resonant frequency so as to interrupt the formation of an elongated tail from the ligament 22 as shown in Fig. 2B creating a more nearly spherical droplet 20 as shown in Fig. 2C with only an abbreviated tail 22 as contrasted with the elongated tail 22 shown in Fig. 1F.

[0022] In accordance with this invention, the piezoelectric transducer 10 is chosen so as to have a high resonant frequency. The resonant frequency of the transducer 10 is in excess of 50 kHz and preferably greater than 75 kHz with 90-300 kHz being preferred and representing the preferred embodiment. The higher harmonic frequency which is excited by the trailing pulse between times E and F is in excess of 150 kHz with frequencies in excess of 200 kHz preferred and 235 kHz utilized in the preferred embodiment. For the preferred embodiment were the resonant frequency is 90-300 kHz and the higher harmonic is 235-800 kHz, the pulse 23 between times B and C is preferably 14.5 microseconds which pulls the ink back in the meniscus 18 to the position shown in prior art Figure 1C. The pulse 23 between times B and C is followed by a dead time between time C and E which is preferably 1.5 microseconds followed by the shorter pulse 25 between times E and F of 3.0 microseconds in duration so as to excite the higher harmonic of 235 kHz. This higher harmonic resonant of frequency of 235 kHz creates a pressure wave with a high acceleration component that disturbs the ink flow in the orifice as the ink flows out as discussed above. Tail formation as a consequence is greatly affected such that the tail breaks off from the meniscus 18 much earlier than in the single pulse approach of the prior art. The shorter tail 22 can now travel with the head of the drop 20 because the liquid surface tension is now high enough to keep the drop together and accelerate the shorter tail to the same velocity as the head of the drop.

[0023] In accordance with another important aspect of the invention, increasing the fluidic resonant frequency improves throw distance of the drops. For example, increasing the fluidic resonant frequency or Helmholtz frequency from 45 kHz to 90 kHz and correspondingly increasing the natural ringing frequency of the transducer from 45 kHz to 90 kHz can in of itself increase the drop tail velocity from 4.5 meters per second to 5.5 meters per second with the head traveling at 6.5 milliseconds so as increase the throw distance of the drop at least 75 percent. With the addition of another pulse with a short duration so as to excite the higher harmonic resonant frequency such as for example 235 kHz, the tail of the drop may be broken off sufficiently earlier so as to increase the tail velocity to 6.5 to 7 meters per second. This produces ink drops with throw distances increased by as much as 200 percent.

[0024] It will be appreciated that the same higher harmonic frequencies which achieve early droplet break off and shorter tails may be achieved by the use of a shorter pulse before or after a longer pulse. As shown in Fig. 2A', a shorter pulse 27 between times G and H precedes the longer pulse between times B and C. The effect is the same since the shorter pulse 27 following the longer pulse 23 is capable of exciting the higher harmonic frequency, i.e. a frequency in excess of 150 kHz and as high as 235 kHz in the preferred embodiment.

[0025] Referring to Fig. 3, a system is shown including a plurality of fluid or jet devices of the type shown in Fig. 2B and 2C incorporated in a head 24 with orifices 16 shown of exaggerated size. The head 24 is driven by a signal generator 26 connected to a power supply 28 and a voltage regulator 30. A timing circuit 32 is coupled to the signal generator so as to generate voltage drive pulses for the transducers of the fluid or ink jet devices incorporated in the head 24 which include a longer pulse of the type described above as well as a shorter pulse which may precede or follow the longer pulse.

[0026] As shown in Fig. 3, a droplet 20 is being ejected in a direction indicated by the arrow 34 toward a target or object 36 carried by a conveyor 38. In many applications, it may be desirable or necessary to separate the head 24 from the target 36 by some distance. It is therefore important to achieve long throw distances and high drop velocity with little or no tail in order to achieve high resolution drop and accuracy in accordance with this invention.

[0027] It should also be appreciated that the invention is not limited to any particular type of wave shape. As shown in Fig. 4, the wave shape need not be square or rectangular but may be almost sawtoothed and the voltage level between the longer pulse 37 and the shorter pulse 39 need not go to zero but need only to have a substantially lesser amplitude than the peaks of the longer pulse and the shorter pulse. In this regard, the longer pulse 37 between times I and J shown in Fig. 4 is almost triangular as is the shorter pulse 39 between times K and L. Moreover, the time separating the longer pulse and the shorter pulse between times J and K is characterized by a non-zero varying voltage as is the voltage following the shorter pulse between time K and L. The overall effect is to excite the natural ringing or resonant frequency of the piezo transducer with the longer pulse 37 between times I and J and the higher harmonic with the shorter pulse between times K and L. Of course, as indicated previously, the shorter pulse may precede or follow the longer pulse using the wave forms of Fig. 4. Alternate pulses 37a and 37b are shown in Fig. 4a where the shorter pulse follows the longer pulse.

[0028] As indicated previously, the preferred embodiment, whether utilizing the wave form of Figs. 2A, 2A', 4 or 4A, provides for a longer pulse of 14.5 microseconds and a shorter pulse 3.0 microseconds. Other embodiments, depending upon the resonant frequency of the transducer, may incorporate other durations. For example, the pulse of the longer duration may be between

5 microseconds and 100 microseconds whereas the pulse of the shorter duration may be between .5 microseconds and 6 microseconds. Similarly, time between pulses may vary between .1 microsecond and 5 microseconds.

[0029] Referring again to Fig. 4, the waveform described therein is particularly desirable to achieve stable performance. In order to achieve the waveform of Fig. 4, it would be desirable to include a resistance in series with the piezoelectric transducer. In this regard, reference is made to Fig. 5 wherein a resistor 40 of at least 100 ohms is connected in series with a transducer 10 located between an electrode 42 and an electrode 44. As shown, the transducer 10 is a length mode transducer which achieves the transducer expansion and contraction shown in Figs. 2B and 2C and has a length less than .6 inches. The transducer 10 is coupled to the chamber 14 through a diaphragm 46. An inlet 48 leading into the chamber 14 is also shown. In the preferred embodiment, the chamber 14 would have a sufficiently small volume so as to assure a high Helmholtz resonant frequency in excess of 50 kHz and preferably approaching 90 kHz and would be embodied in the printhead shown in U.S. Patent Application Serial No. 08/828,758 filed March 25, 1997 which is incorporated by reference. Further details concerning the particular impulse ink jet disclosed in Fig. 5 may be found with reference to U.S. Patent No. 4,697,193 which is incorporated herein by reference although it will be understood that Helmholtz frequencies in excess of 50 kHz are not disclosed in the aforesaid patent.

[0030] As shown in Fig. 6, a voltage waveform similar to that shown in Fig. 4a is superimposed on the chamber pressure of the fluid jet device depicted in Figs. 2B and 2C. It will be noted that the chamber pressure variation corresponding to the resonant frequency of the device is basically sinusoidal and decaying as a result of the longer pulse 37b but carries a slight ripple as a result of the shorter pulse 39b which excites the higher harmonic of the device. The ripple which corresponds to the higher harmonic of the device takes the shape of a step 50 coinciding with the trailing edge 52 of the shorter pulse 39b actually causes the tail of the droplet to break off to create a smaller droplet as shown in Fig. 2C. As a result, the droplet is able to travel further at higher velocities; i.e., the throw distance is increased.

[0031] It will be appreciated that the higher harmonic frequency of the transducer must be excited in a way so as to assure that the tail of the droplet is accelerated into the droplet and not decelerated. In order to depict the proper relationship between the resonant frequency of the transducer and the higher harmonic frequency, reference is made to Fig. 6 wherein the resonant frequency is depicted by the generally sinusoidal wave shape 48 and the higher harmonic frequency is depicted by the sinusoidal waveform 50 properly phased by the timing of the pulses such that a specific high harmonic frequency is excited. This relationship between the higher harmonic and the resonant frequency will assure that the tail is broken off and the remainder of the tail which stays with the droplet will be accelerated into the droplet head thereby improving throw distance and velocity. Although particular transducers and particular voltage waveforms have been shown, it will be appreciated that this invention may be practiced with a variety of devices including bubble jets where the fluid or ink itself serves as a transducer. In addition, the invention may be practiced with other shapes and forms of transducers, i.e., not necessarily length mode expander transducers. For example, benders and shared wall transducers may be used. Moreover, the particular drive waveform may not be a voltage but any energy pulse so as to energize and deenergize the transducer at the appropriate times to assure the excitation of the resonant frequency as well as the higher harmonic frequency. Finally, the fluid need not be ink but may comprise any liquid which must be jetted in droplet form for any purpose, e.g. metering.

Claims

1. A method of operating an impulse fluid jet device comprising a chamber (14) having an orifice (16) for ejection of droplets (20) in response to different energy pulses (23,25; 37, 39; 37a, 39a) applied to a transducer (10), said transducer (10) having a resonant frequency and a higher harmonic frequency, said method being **characterized by** the following steps:

   generating one energy pulse (23; 37; 37a) for one duration coupled to the transducer (10) for exciting the resonant frequency of the transducer (10), thus
   initiating the ejection of a droplet (20) having a head portion and an attached tail (22) portion in response to the one energy pulse (23), wherein the tail portion (22) is integral with the fluid at the orifice (16);
   generating another energy pulse (25; 39; 39a) of another duration coupled to the transducer (10), said other duration being substantially shorter than said one duration for exciting the higher harmonic frequency of the transducer (10), wherein the higher harmonic frequency generates a pressure wave such that the tail portion (22) breaks from the fluid at the orifice (16) and the tail portion (22) and the head portion of the droplet (20) travel at substantially the same velocity toward a target (36).

2. The method of claim 1 wherein said device has a Helmholtz fluidic frequency in excess of 50 kHz.

3. The method of claim 1 or 2 wherein said resonant frequency is greater than 75 kHz and said higher

harmonic frequency is greater than 200 kHz.

4. The method of at least one of the preceding claims wherein said one duration is greater than 5 µsec.

5. The method of at least one of the preceding claims wherein said other duration is greater than 0,5 µsec.

6. The method of claim 1 wherein said one duration is between 5 µsec and 100 µsec and said other duration is between 0,5 µsec and 6 µsec.

7. The method of at least one of the preceding claims further comprising the step of waiting a period of time between generating the one (23; 37; 37a) and the other energy pulses (25; 39; 39a).

8. The method of claim 7 wherein a time delay between said one energy pulse (23; 37; 37a) and said other energy pulse (25; 39; 39a) is equal to at least 0,1 µsec.

9. The method of claim 7 wherein a time delay between said one energy pulse (23; 37; 37a) and said other energy pulse (25; 39; 39a) is between 0,1 µsec and 5 µsec.

10. The method of at least one of the preceding claims wherein the resonant frequency to the transducer (10) is in excess of 50 kHz.

11. The method of at least one of the preceding claims wherein the higher harmonic frequency is in excess of 150 kHz.

12. An impulse fluid jet apparatus comprising:

a fluid jet chamber (14) having an orifice (16);
a piezoelectric transducer (10) coupled to said jet chamber (14) so as to expand therein, said transducer having a resonant frequency and a higher harmonic frequency;
pulse generating circuitry (26) coupled to the transducer (10) for generating pulses (23, 25; 37, 39; 37a, 39a) for changing the state of energization of the transducer (10) for ejecting droplets (20) of fluid from the orifice (16) on demand, **characterized in that** said circuitry (26) generates one pulse (23; 37; 37a) having a first duration thus exciting said resonant frequency and initiating the ejection of a droplet (20) of fluid, said droplet (20) having a head portion and an attached tail portion (22), the droplet tail portion (22) being integral with the fluid at the orifice (16), and wherein said circuitry (26) generates another pulse (25; 39; 39a) having a duration substantially shorter than said one pulse (23; 37; 37a), thus exciting said higher harmonic frequency of the transducer (10) and generating a pressure wave that breaks the tail portion (22) of the droplet (20) from said fluid at the orifice (16), such that the tail portion (22) and the head portion travel at substantially the same velocity toward a target (36).

13. The apparatus of claim 12 wherein the other pulse (25; 39; 39a) follows the one pulse (23; 37; 37a) in time.

14. The apparatus of claim 12 wherein the other pulse (25; 39; 39a) precedes the one pulse (23; 37; 37a) in time.

15. The apparatus of at least one of the claims 12 to 14 wherein said transducer (10) is of the length mode expander type.

16. The apparatus of at least one of the claims 12 to 15 wherein said resonant frequency of the transducer is greater than 50 kHz and said higher harmonic frequency is greater than 200 kHz.

17. The apparatus of at least one of the claims 12 to 16 wherein said one pulse (23; 37; 37a) has a duration greater than 5 µsec.

18. The apparatus of at least one of the claims 12 to 17 wherein said other pulse (25; 39; 39a) has a duration greater than 0,5 µsec.

19. The apparatus of at least one of the claims 12 to 18 wherein said pulse generating circuitry (26) generates said one pulse (23; 37; 37a) having a duration between 5 µsec and 100 µsec and said other pulse (25; 39; 39a) having a duration between 0,5 µsec and 6 µsec.

20. The apparatus of at least one of the claims 12 to 19 wherein said pulse generating circuitry (26) creates a delay between said one pulse (23; 37; 37a) and said other pulse (25; 39; 39a) in excess of 0,1 µsec.

21. The apparatus of at least one of the claims 12 to 20 wherein said pulse generating circuitry generates a delay between said one pulse (23; 37; 37a) and said other pulse (25; 39; 39a) between 0,1 µsec and 5 µsec.

22. The apparatus of at least one of the claims 12 to 21 wherein said pulse generating circuitry includes a resistance (40) in series with said transducer (10) of at least 100 ohms, such that the waveform of the other pulse (25; 39; 39a) is sufficiently square to excite the higher harmonic frequency generating the pressure wave.

23. The apparatus of claim 22 wherein said resistance (40) is between 100 and 500 ohms.

24. The apparatus of at least one of the claims 12 to 23 wherein said higher harmonic frequency of the transducer (10) is in excess of 150 kHz.

25. The apparatus of at least one of the claims 12 to 24 wherein said resonant frequency of the transducer (10) is in excess of 50 kHz.

Patentansprüche

1. Verfahren zum Betreiben einer Impulsfluidstrahlvorrichtung enthaltend eine Kammer (14) mit einer Öffnung (16) zum Ausstoßen von Tröpfchen (20) als Antwort auf verschiedene Energieimpulse (23, 25; 37, 39; 37a, 39a), welche an einen Wandler (10) angelegt werden, wobei der Wandler (10) eine Resonanzfrequenz und eine höhere harmonische Frequenz hat, und das Verfahren **gekennzeichnet ist durch** die folgenden Schritte:

   Erzeugen eines Energieimpulses (23; 37; 37a) für eine Dauer, gekuppelt mit dem Wandler (10), um die Resonanzfrequenz des Wandlers (10) zu erregen und so das Ausstoßen eines Tröpfchens (20) einzuleiten, welches einen Kopfabschnitt und einen anhängenden Schwanzabschnitt (22) hat als Antwort auf den einen Energieimpuls (23), wobei der Schwanzabschnitt (22) mit dem Fluid an der Öffnung (16) integral ist; Erzeugen eines anderen Energieimpulses (25; 39; 39a) mit einer anderen Dauer, gekuppelt mit dem Wandler (10), wobei die andere Dauer wesentlich kürzer ist als die eine Dauer, um die höhere harmonische Frequenz des Wandlers (10) zu erregen, wobei die höhere harmonische Frequenz eine Druckwelle erzeugt, so dass der Schwanzabschnitt (22) vom Fluid an der Öffnung (16) abbricht und der Schwanzabschnitt (22) und der Kopfabschnitt des Tröpfchens (20) mit im wesentlichen der gleichen Geschwindigkeit zu einem Ziel (36) hin fliegen.

2. Verfahren nach Anspruch 1, wobei die Vorrichtung eine Helmholtz-Fluidfrequenz von über 50 kHz hat.

3. Verfahren nach Anspruch 1 oder 2, wobei die Resonanzfrequenz größer ist als 75 kHz, und die höhere harmonische Frequenz größer ist als 200 kHz.

4. Verfahren nach mindestens einem der vorhergehenden Ansprüche, wobei die eine Dauer größer als 5 µs ist.

5. Verfahren nach mindestens einem der vorhergehenden Ansprüche, wobei die andere Dauer größer als 0,5 µs ist.

6. Verfahren nach Anspruch 1, wobei die eine Dauer zwischen 5 µs und 100 µs liegt und die andere Dauer zwischen 0,5 µs und 6 µs.

7. Verfahren nach mindestens einem der vorhergehenden Ansprüche, ferner enthaltend den Schritt des Wartens für einen Zeitraum zwischen dem Erzeugen des einen (23; 37; 37a) und des anderen Energieimpulses (25; 39; 39a).

8. Verfahren nach Anspruch 7, wobei eine Zeitverzögerung zwischen dem einen Energieimpuls (23; 37; 37a) und dem anderen Energieimpuls (25; 39; 39a) mindestens 0,1 µs beträgt.

9. Verfahren nach Anspruch 7, wobei eine Zeitverzögerung zwischen dem einen Energieimpuls (23; 37; 37a) und dem anderen Energieimpuls (25; 39; 39a) zwischen 0,1 µs und 5 µs liegt.

10. Verfahren nach mindestens einem der vorhergehenden Ansprüche, wobei die Resonanzfrequenz zum Wandler (10) über 50 kHz liegt.

11. Verfahren nach mindestens einem der vorhergehenden Ansprüche, wobei die höhere harmonische Frequenz über 150 kHz liegt.

12. Impulsfluidstrahlgerät enthaltend:

    eine Fluidstrahlkammer (14) mit einer Öffnung (16);
    einen piezoelektrischen Wandler (10), welcher mit der Strahlkammer (14) gekuppelt ist, um darin zu expandieren, wobei der Wandler eine Resonanzfrequenz hat und eine höhere harmonische Frequenz; wobei der Impuls erzeugende Schaltkreis (26) an den Wandler (10) gekuppelt ist, um Impulse (23, 25; 37, 39; 37a, 39a) zu erzeugen zur Änderung des Zustandes der Energiezufuhr zum Wandler (10) zum Ausstoßen von Tröpfchen (20) des Fluids aus der Öffnung (16) nach Bedarf, **dadurch gekennzeichnet,** das der Schaltkreis (26) einen Impuls (23; 37; 37a) erzeugt, welcher eine erste Dauer hat und so die Resonanzfrequenz erregt und das Ausstoßen eines Fluidtröpfchens (20) einleitet, wobei das Tröpfchen (20) einen Kopfabschnitt und einen anhängenden Schwanzabschnitt (22) aufweist, der Tröpfchen-Schwanzabschnitt (22) mit dem Fluid an der Öffnung (16) integral ist, und der Schaltkreis (26) einen anderen Impuls (25; 39; 39a) erzeugt, welcher eine wesentlich kürzere Dauer hat als der eine

Impuls (23, 37; 37a) und so die höhere harmonische Frequenz des Wandlers (10) erregt und eine Druckwelle erzeugt, welche den Schwanzabschnitt (22) des Tröpfchens (20) des Fluids an der Öffnung (16) abbricht, so dass der Schwanzabschnitt (22) und der Kopfabschnitt mit im wesentlichen der gleichen Geschwindigkeit zu einem Ziel (36) fliegen.

13. Gerät nach Anspruch 12, wobei der andere Impuls (25; 39; 39a) dem einen Impuls (23; 37; 37a) zeitlich folgt.

14. Gerät nach Anspruch 12, wobei der andere Impuls (25; 39; 39a) dem einen Impuls (23; 37; 37a) zeitlich vorausgeht.

15. Gerät nach mindestens einem der Ansprüche 12 bis 14, wobei der Wandler (10) vom Längsmodus-Expandertyp ist.

16. Gerät nach mindestens einem der Ansprüche 12 bis 15, wobei die Resonanzfrequenz des Wandlers größer ist als 50 kHz und die höhere harmonische Frequenz größer ist als 200 kHz.

17. Gerät nach mindestens einem der Ansprüche 12 bis 16, wobei der eine Impuls (23; 37; 37a) eine Dauer von mehr als 5 µs hat.

18. Gerät nach einem der Ansprüche 12 bis 17, wobei der andere Impuls (25; 39; 39a) eine Dauer von mehr 0,5 µs hat.

19. Gerät nach mindestens einem der Ansprüche 12 bis 18, wobei der Impuls erzeugende Schaltkreis (26) den einen Impuls (23; 37; 37a) erzeugt, welcher eine Dauer zwischen 5 µs und 100 µs hat, und den anderen Impuls (25; 39; 39a), welcher eine Dauer zwischen 0,5 µs und 6 µs hat.

20. Gerät nach mindestens einem der Ansprüche 12 bis 19, wobei der Impuls erzeugende Schaltkreis (26) eine Verzögerung zwischen dem einen Impuls (23; 37; 37a) und dem anderen Impuls (25; 39; 39a) von über 0,1 µs erzeugt.

21. Gerät nach mindestens einem der Ansprüche 12 bis 20, wobei der Impuls erzeugende Schaltkreis eine Verzögerung zwischen dem einen Impuls (23; 37; 37a) und dem anderen Impuls (25; 39; 39a) zwischen 0,1 µs und 5 µs erzeugt.

22. Gerät nach mindestens einem der Ansprüche 12 bis 21, wobei der Impuls erzeugende Schaltkreis einen Widerstand (40) in Reihe mit dem Wandler (10) von mindestens 100 Ohm aufweist, so dass die Wellenform des anderen Impulses (25; 39; 39a) ausreichend rechteckig ist, um die höhere harmonische Frequenz zu erregen, welche die Druckwelle erzeugt.

23. Gerät nach Anspruch 22, wobei der Widerstand (40) zwischen 100 und 500 Ohm liegt.

24. Gerät nach mindestens einem der Ansprüche 12 bis 23, wobei die höhere harmonische Frequenz des Wandlers über 150 kHz liegt.

25. Gerät nach mindestens einem der Ansprüche 12 bis 24, wobei die Resonanzfrequenz des Wandlers über 50 kHz liegt.

Revendications

1. Procédé d'exploitation d'un dispositif à jet de fluide par impulsions comprenant une chambre (14) ayant un orifice (16) pour l'éjection de gouttelettes (20) en réponse à différentes impulsions d'énergie (23, 25; 37, 39; 37a, 39a) appliquées à un transducteur (10), ledit transducteur (10) ayant une fréquence de résonance et une fréquence harmonique supérieure, ledit procédé étant **caractérisé par** les étapes consistant à:

générer une première impulsion d'énergie (23; 37; 37a) pendant une première durée appliquée au transducteur (10) en vue d'exciter la fréquence de résonance du transducteur (10), et ainsi
déclencher l'éjection d'une gouttelette (20) ayant une partie tête et une partie queue attachée (22) en réponse à la première impulsion d'énergie (23), la partie queue (22) étant d'un seul tenant avec le fluide au niveau de l'orifice (16);
générer une autre impulsion d'énergie (25; 39; 39a) d'une autre durée appliquée au transducteur (10), ladite autre durée étant sensiblement plus courte que ladite première durée en vue d'exciter la fréquence harmonique supérieure du transducteur (10), ladite fréquence harmonique supérieure générant une onde de pression telle que la partie queue (22) se sépare du fluide au niveau de l'orifice (16) et la partie queue (22) et la partie tête de la gouttelette (20) se déplacent sensiblement à la même vitesse vers une cible (36).

2. Procédé selon la revendication 1, dans lequel ledit dispositif a une fréquence fluidique de Helmholtz supérieure à 50 kHz.

3. Procédé selon la revendication 1 ou 2, dans lequel ladite fréquence de résonance est supérieure à 75

kHz et ladite fréquence harmonique supérieure est supérieure à 200 kHz.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite première durée est supérieure à 5 µs.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite autre durée est supérieure à 0,5 µs.

6. Procédé selon la revendication 1, dans lequel ladite première durée est comprise entre 5 µs et 100 µs et ladite autre durée est comprise entre 0,5 µs et 6 µs.

7. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre l'étape consistant à attendre un laps de temps entre la génération de la première (23; 37; 37a) et de l'autre impulsion d'énergie (25; 39; 39a).

8. Procédé selon la revendication 7, dans lequel un retard temporel entre ladite première impulsion d'énergie (23; 37; 37a) et ladite autre impulsion d'énergie (25; 39; 39a) est égal à au moins 0,1 µs.

9. Procédé selon la revendication 7, dans lequel un retard temporel entre ladite première impulsion d'énergie (23; 37; 37a) et ladite autre impulsion d'énergie (25; 39; 39a) est compris entre 0,1 µs et 5 µs.

10. Procédé selon l'une quelconque des revendications précédentes, dans lequel la fréquence de résonance du transducteur (10) est supérieure à 50 kHz.

11. Procédé selon l'une quelconque des revendications précédentes, dans lequel la fréquence harmonique supérieure est supérieure à 150 kHz.

12. Dispositif à jet de fluide par impulsions, comprenant:

une chambre d'émission de jet de fluide (14) ayant un orifice (16);
un transducteur piézoélectrique (10) couplé à ladite chambre d'émission de jet (14) de manière à s'allonger en son sein, ledit transducteur ayant une fréquence de résonance et une fréquence harmonique supérieure;
un circuit générateur d'impulsions (26) couplé audit transducteur (10) pour générer des impulsions (23, 25; 37, 39; 37a, 39a) en vue de changer l'état d'excitation du transducteur (10) pour éjecter des gouttelettes (20) de fluide par l'orifice (16) à la demande, **caractérisé en ce que** ledit circuit (26) génère une première impulsion (23; 37; 37a) ayant une première durée pour ainsi exciter ladite fréquence de résonance et déclencher l'éjection d'une gouttelette (20) de fluide, ladite gouttelette (20) ayant une partie tête et une partie queue attachée (22), la partie queue (22) de la gouttelette étant d'un seul tenant avec le fluide au niveau de l'orifice (16), et **en ce que** ledit circuit (26) génère une autre impulsion (25; 39; 39a) ayant une durée sensiblement plus courte que ladite première impulsion (23; 37; 37a), pour ainsi exciter ladite fréquence harmonique supérieure du transducteur (10) et générer une onde de pression qui sépare la partie queue (22) de la gouttelette (20) dudit fluide au niveau de l'orifice (16), de sorte que la partie queue (22) et la partie tête se déplacent sensiblement à la même vitesse vers une cible (36).

13. Dispositif selon la revendication 12, dans lequel l'autre impulsion (25; 39; 39a) suit la première impulsion (23; 37; 37a) dans le temps.

14. Dispositif selon la revendication 12, dans lequel l'autre impulsion (25; 39; 39a) précède la première impulsion (23; 37; 37a) dans le temps.

15. Dispositif selon l'une quelconque des revendications 12 à 14, dans lequel ledit transducteur (10) est du type à déformation en mode longitudinal.

16. Dispositif selon l'une quelconque des revendications 12 à 15, dans lequel ladite fréquence de résonance du transducteur est supérieure à 50 kHz et ladite fréquence harmonique supérieure est supérieure à 200 kHz.

17. Dispositif selon l'une quelconque des revendications 12 à 16, dans lequel ladite première impulsion (23; 37; 37a) a une durée supérieure à 5 µs.

18. Dispositif selon l'une quelconque des revendications 12 à 17, dans lequel ladite autre impulsion (25; 39; 39a) a une durée supérieure à 0,5 µs.

19. Dispositif selon l'une quelconque des revendications 12 à 18, dans lequel ledit circuit générateur d'impulsions (26) génère ladite première impulsion (23; 37; 37a) ayant une durée comprise entre 5 µs et 100 µs et ladite autre impulsion (25; 39; 39a) ayant une durée comprise entre 0,5 µs et 6 µs.

20. Dispositif selon l'une quelconque des revendications 12 à 19, dans lequel ledit circuit générateur d'impulsions (26) crée un retard entre ladite première impulsion (23; 37; 37a) et ladite autre impulsion (25; 39; 39a) supérieur à 0,1 µs.

21. Dispositif selon l'une quelconque des revendications 12 à 20, dans lequel ledit circuit générateur d'impulsions (26) génère un retard entre ladite première impulsion (23; 37; 37a) et ladite autre impulsion (25; 39; 39a) compris entre 0,1 µs et 5 µs.

22. Dispositif selon l'une quelconque des revendications 12 à 21, dans lequel ledit circuit générateur d'impulsions (26) comprend une résistance (40) en série avec ledit transducteur (10) d'au moins 100 ohms, de sorte que la forme d'onde de l'autre impulsion (25; 39; 39a) est suffisamment carrée pour exciter la fréquence harmonique supérieure générant l'onde de pression.

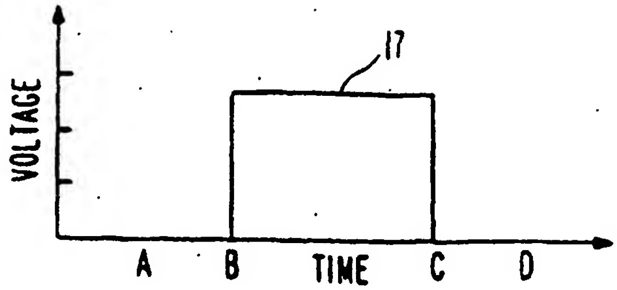
23. Dispositif selon la revendication 22, dans lequel ladite résistance (40) est comprise entre 100 et 500 ohms.

24. Dispositif selon l'une quelconque des revendications 12 à 23, dans lequel ladite fréquence harmonique supérieure du transducteur (10) est supérieure à 150 kHz.

25. Dispositif selon l'une quelconque des revendications 12 à 24, dans lequel ladite fréquence de résonance du transducteur (10) est supérieure à 50 kHz.

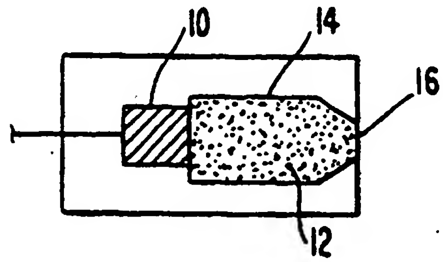
PRIOR ART

Fig. 1A



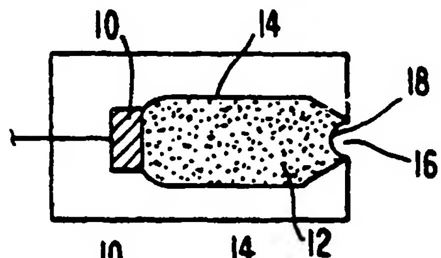
PRIOR ART

Fig. 1B



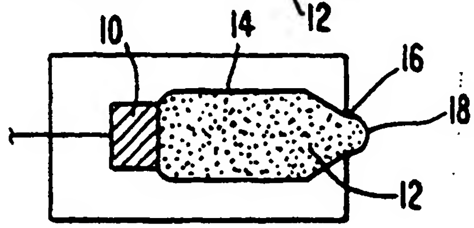
PRIOR ART

Fig. 1C



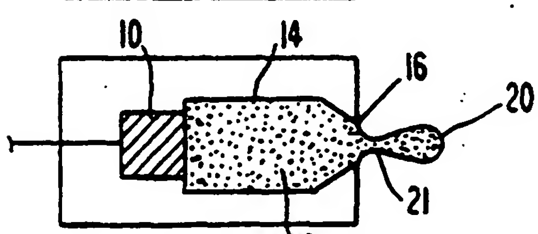
PRIOR ART

Fig. 1D



PRIOR ART

Fig. 1E



PRIOR ART

Fig. 1F

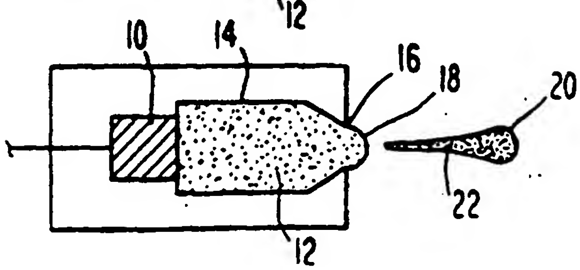


Fig. 2A

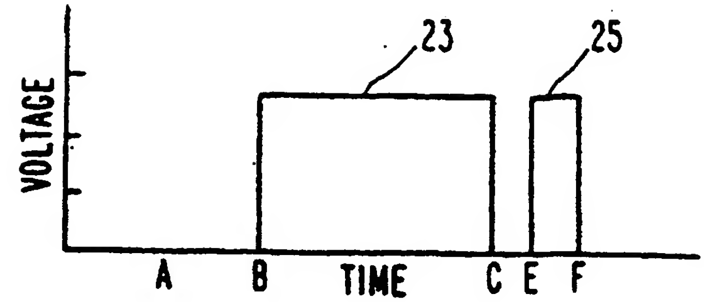


Fig. 2A'

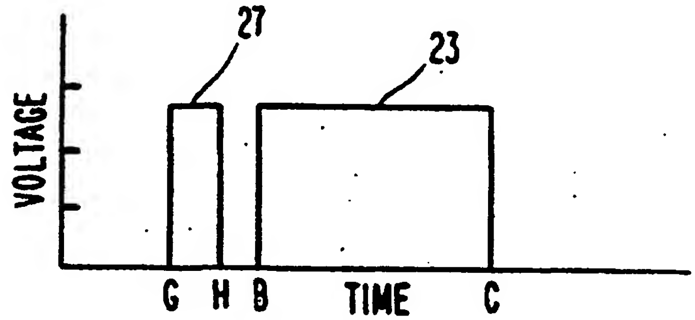


Fig. 2B

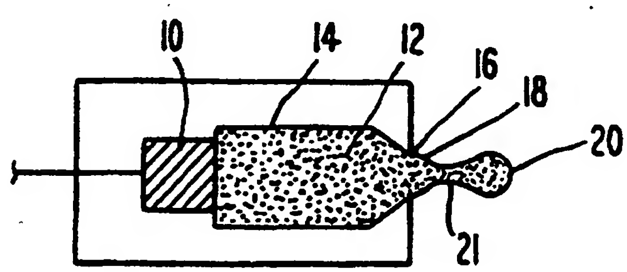
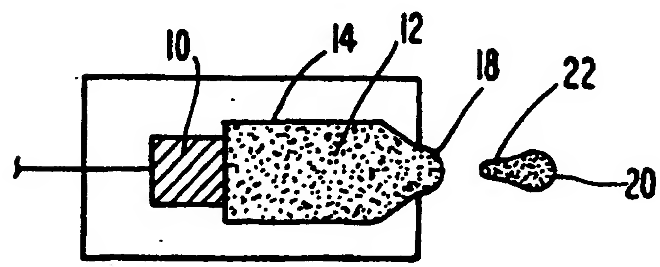


Fig. 2C



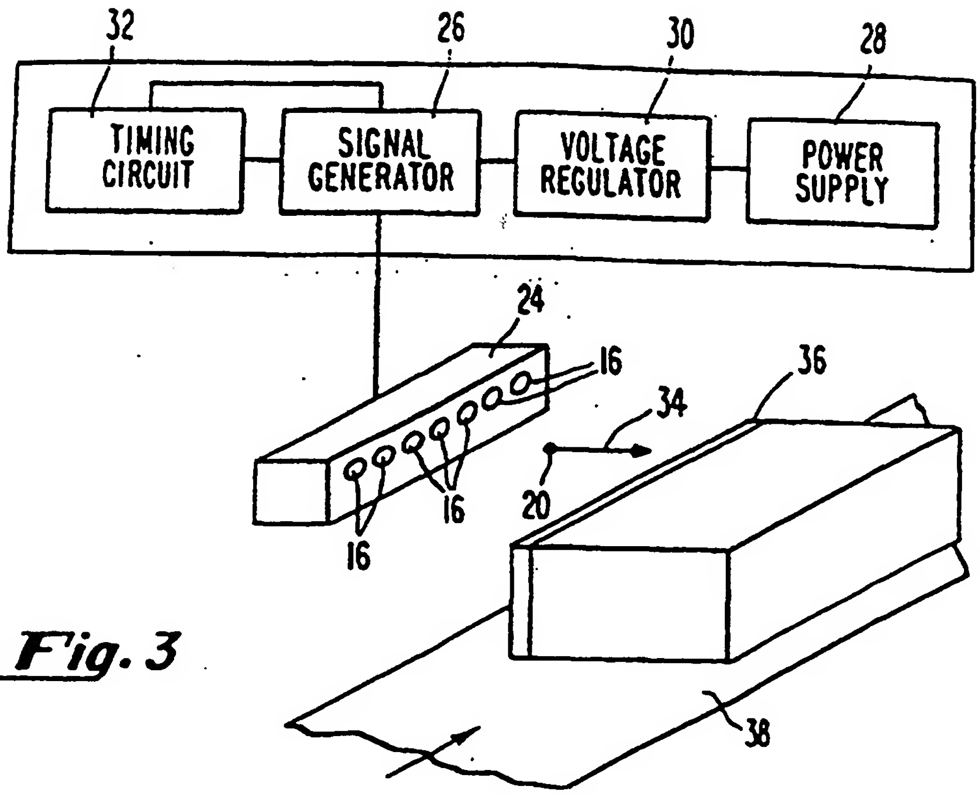


Fig. 3

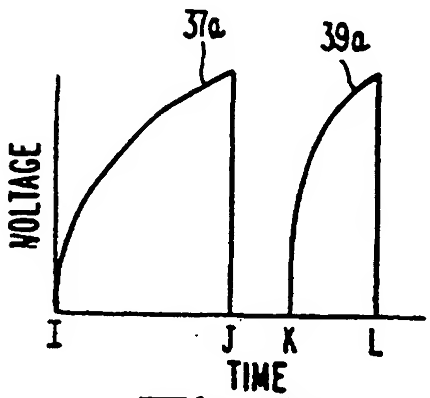


Fig. 4a

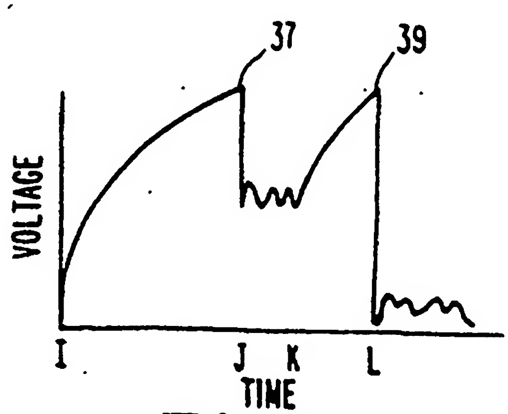


Fig. 4

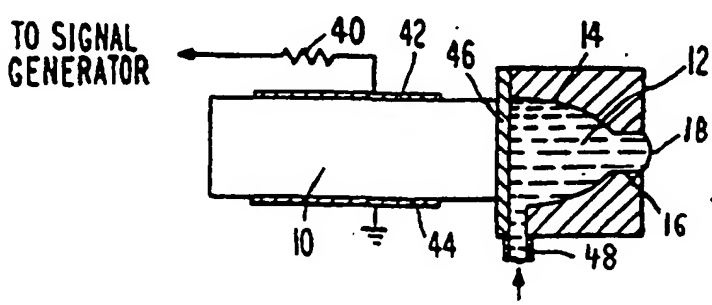


Fig. 5